PB90-234212

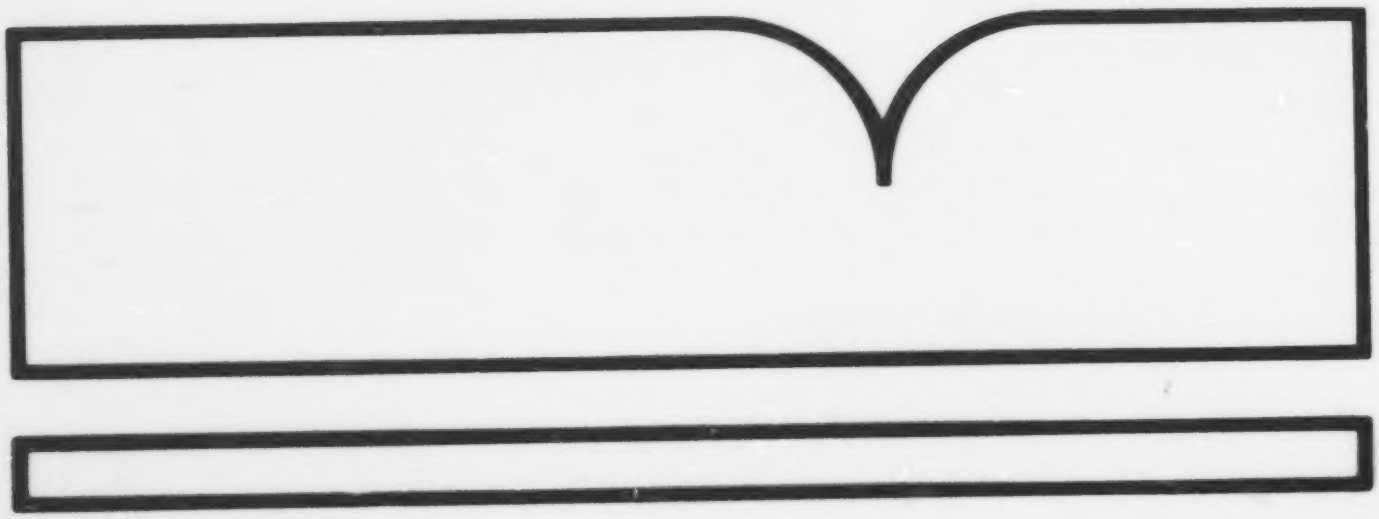
Final Best Demonstrated Available Technology (BDAT) Background Document for D006 Cadmium Wastes Volume 21

Versar, Inc., Springfield, VA

Prepared for:

Environmental Protection Agency, Washington, DC

May 90



U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/530-SW-90- 059U	2.	3. PB90-234212
4. Title and Subtitle FINAL BDAT BACKGROUND DOCUMENT FOR D006 CADMIUM WASTES			5. Report Date May 1990 6.
7. Author(s) Rosengrant/ Labiosa/OSW			8. Performing Organization Rept. No
9. Performing Organization Name and Address U.S. EPA Office of Solid Waste 401 M. Street SW Washington, DC 20460			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) 68-W9-0068 (G)
12. Sponsoring Organization Name and Address Versar, Inc.			13. Type of Report & Period Covered Background Document - 5/90 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This background document provides the Agency's technical support and rationale for the development of treatment standards for the constituents to be regulated for the above-mentioned wastes.

Sections 2 through 6 present waste-specific information for D006 wastes.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
RELEASE UNLIMITED	UNCLASSIFIED	0
	20. Security Class (This Page) UNCLASSIFIED	22. Price 0

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

EPA/530-SW-90-059H
PB90-234212

FINAL
BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) BACKGROUND DOCUMENT FOR

D006 CADMIUM WASTES

Larry Rosengrant, Chief
Treatment Technology Section

Jose E. Labiosa
Project Manager

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, DC 20460

May 1990

ACKNOWLEDGMENTS

This document was prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract No. 68-W9-0068. Mr. Larry Rosengrant, Chief, Treatment Technology Section, Waste Treatment Branch, served as the EPA Program Manager during the preparation of this document and the development of treatment standards for the D006 wastes. The technical project officer for the waste was Mr. Jose Labiosa. Mr. Steven Silverman served as legal advisor.

Versar personnel involved in the preparation of this document included Mr. Jerome Strauss, Program Manager; Mr. Stephen Schwartz, Assistant Program Manager; Mr. Edwin F. Rissmann, Principal Investigator and Author; Ms. Justine Alchowiak, Quality Assurance Officer; Ms. Martha Martin, Technical Editor; and Ms. Sally Gravely, Program Secretary.

TABLE OF CONTENTS

Section			Page No.
1.	INTRODUCTION AND SUMMARY		1-1
2.	INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION		2-1
	2.1	Industries Affected and Process Descriptions	2-1
		2.1.1 Production of Inorganic Cadmium Compounds	2-1
		2.1.2 Users of Inorganic Cadmium Compounds	2-3
	2.2	Waste Characterization	2-4
	2.3	Determination of Waste Treatability Group	2-5
3.	APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGIES		3-1
	3.1	Applicable Treatment Technologies	3-1
		3.1.1 Applicable Technologies for Nonwastewaters	3-1
		3.1.2 Applicable Technologies for Cadmium-Containing Batteries	3-3
		3.1.3 Applicable Technologies for Wastewaters	3-4
	3.2	Demonstrated Treatment Technologies	3-4
		3.2.1 Demonstrated Technologies for Nonwastewaters	3-4
		3.2.2 Demonstrated Technologies for Cadmium-Containing Batteries	3-5
		3.2.3 Demonstrated Technologies for Wastewaters	3-6
4.	PERFORMANCE DATA		4-1
	4.1	Performance Data for Nonwastewaters	4-2
		4.1.1 Performance Data for High-Temperature Metals Recovery	4-2
		4.1.2 Performance Data for Stabilization	4-3
	4.2	Performance Data for Wastewaters	4-3
5.	DETERMINATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)		5-1
	5.1	BDAT for Nonwastewaters	5-1
	5.2	BDAT for Wastewaters	5-2

TABLE OF CONTENTS (CONTINUED)

6. DEVELOPMENT OF BDAT TREATMENT STANDARDS 6-1

6.1 BDAT Treatment Standards for Nonwastewaters 6-1
6.2 BDAT Treatment Standards for Wastewaters 6-1
6.3 BDAT Treatment Standards for Cadmium Battery Wastes 6-2

7. REFERENCES 7-1

LIST OF TABLES

		Page No.
Table 1-1	BDAT Treatment Standards for D006 - Wastewaters	1-4
Table 1-2	BDAT Treatment Standards for D006 - Nonwastewaters	1-4
Table 1-3	BDAT Treatment Standards for D006 - Cadmium Batteries	1-4
Table 4-1	Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Waelz Kiln (EPA-Collected Data)	4-5
Table 4-2	Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Plasma Arc Reactor	4-7
Table 4-3	Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Rotary Hearth/ Electric Furnace	4-8
Table 4-4	Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Molten Slag System	4-9
Table 4-5	Treatment Performance Data for Stabilization of K061 Waste (EPA-Collected Data)	4-10
Table 4-6	Treatment Performance Data for Stabilization of F006 Waste	4-12
Table 4-7	Stabilization of Ferrous Foundry Wastes	4-14
Table 4-8	Treatment Performance Data for Chemical Precipitation and Vacuum Filtration	4-15
Table 6-1	BDAT Treatment Standards for D006 Nonwastewaters	6-3
Table 6-2	BDAT Treatment Standards for D006 Wastewaters	6-3
Table 6-3	BDAT Treatment Standards for D006 - Cadmium Batteries	6-3

1. INTRODUCTION AND SUMMARY

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act (RCRA) as enacted by the Hazardous and Solid Waste Amendments (HSWA) on November 8, 1984, the Environmental Protection Agency (EPA) is establishing treatment standards based on the best demonstrated available technology (BDAT) for cadmium-containing wastes. These wastes are identified in 40 CFR 261.24 under the waste code D006. Compliance with these treatment standards is a prerequisite for placement of these wastes in facilities designated as land disposal units according to 40 CFR Part 268. The effective date of final promulgated treatment standards for D006 wastes will be August 8, 1990.

This background document presents the Agency's rationale and technical support for developing regulatory standards for these wastes. Sections 2 through 6 present waste-specific information for the D006 wastes. Section 2 presents the number and location of facilities believed to be affected by the land disposal restrictions, the waste-generating process, and waste characterization data. It is possible that other industrial operations generating cadmium wastes may not have been covered in Section 2. Section 3 discusses the technologies used to treat the waste (or similar wastes), and Section 4 presents available performance data, including data on which treatment standards are based. Section 5 explains EPA's determination of BDAT. The treatment standards for cadmium wastes are determined in Section 6.

The BDAT program and promulgated methodology are more thoroughly described in two additional documents: Methodology for Developing BDAT Treatment Standards (USEPA 1989a) and Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") (USEPA 1988a). The petition process to be followed in requesting a variance from the BDAT treatment standards is discussed in the methodology document (USEPA 1989a).

Based on responses to EPA's 1986 National Survey of Hazardous Waste Generators, the Agency has gathered information indicating that at least three facilities presently generate D006 wastes from the production of cadmium pigments and that at least seven other facilities produce the wastes from the manufacture of other cadmium compounds. The battery and metal finishing industries also include a large number of generators of cadmium-containing wastes.

D006 wastes are generated as either nonwastewaters or wastewaters. For the purpose of determining BDAT and compliance with the promulgated standards, a wastewater is defined by the Agency as a waste containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Wastes not meeting this definition must comply with the treatment standards for nonwastewaters. The Agency is promulgating treatment standards for D006 as proposed. Nonwastewater forms of D006 are divided into two subcategories: (1) cadmium batteries and (2) other cadmium nonwastewaters. All wastewater forms of D006 wastes must meet the same treatment standards.

Stabilization is BDAT for D006 nonwastewaters (other than cadmium-containing batteries). At proposal, the performance data available to EPA showed that wastes similar to D006 wastes could be treated by stabilization so that a treatment level of 0.14 mg/l, as measured by TCLP, could be achieved. Commenters responding to the treatment standards submitted data on the stabilization of D006 wastes showing that the standard of 0.14 mg/l, measured by TCLP, may not be achievable for all

---

* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, the quantity of total suspended solids is measured by Method 209c (Total Suspended Solids Dried at 103 to 105°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition (APHA, AWWA, and WPCF 1985).

D006 wastes. EPA was unable to determine from these data whether a separate treatability subcategory was merited. However, these data support promulgating a treatment standard of 1.0 mg/l as measured by TCLP.

Thermal recovery is BDAT for D006 nonwastewaters in the "Cadmium-Containing Battery Subcategory" based on thermal recovery data available for K061 wastes. EPA has determined that well-designed and well-operated high-temperature recovery furnaces can treat D006 wastes such that the concentration levels of cadmium left behind in furnace residues (i.e., slag or clinker) are allowable for land disposal under Section 3004(m) of HSWA. However, the air pollution control devices (APCDs) of these high-temperature furnaces can generate wastewater and nonwastewater forms of D006 that may require further treatment for cadmium as a prerequisite for land disposal. For the purpose of the rule, wastes from these APCDs that must meet the TCLP toxicity criteria for cadmium are no longer considered D006 wastes belonging to the D006 wastes in the Cadmium-Containing Battery Subcategory. The APCD wastes are instead considered nonwastewater and wastewater forms of D006 wastes. Applicable treatment standards for D006 wastes must then be met prior to disposal. EPA's determination of BDAT and the provisions for APCD wastes are supported by comments submitted on the promulgated standards for D006 in the Cadmium-Containing Battery Subcategory.

Chemical precipitation followed by filtration is BDAT for D006 wastewaters. The data available to EPA show that a treatment standard of 0.20 mg/l is achievable for D006 wastewaters. However, EPA recognizes the diversity of wastes that qualify as hazardous under the D006 classification. These wastewaters include those from APCD systems in use at facilities using high-temperature metals recovery technologies, wastewater forms of D006 wastes generated by chemical and pigment production facilities, and a wide variety of other cadmium-containing aqueous solutions.

Table 1-1 BDAT Treatment Standard for D006 - Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Cadmium	1.0

Table 1-2 BDAT Treatment Standard for D006 - Nonwastewaters

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Cadmium	1.0

Table 1-3 BDAT Treatment Standard for D006 - Commercial Cadmium Battery Wastes

THERMAL RECOVERY AS A METHOD OF TREATMENT

2. INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

As defined in 40 CFR 261.24, D006 wastes are wastes that exhibit the characteristic of EP toxicity for cadmium. In other words, D006 wastes have a cadmium concentration of greater than 1.0 mg/l, as measured by the EP Toxicity Leaching Procedure. Section 2.1 describes the industries believed to be affected by the land disposal restrictions for D006 wastes and describes the processes identified by EPA that may generate these wastes. It is possible that some industries generating D006 wastes are not discussed in this section. Section 2.2 summarizes the available waste characterization data for these wastes. Section 2.3 uses the Agency's analysis of the sources of D006 wastes and waste composition to divide D006 wastes into several waste treatability groups.

2.1 Industries Affected and Process Descriptions

The industries affected by the land disposal restrictions for D006 wastes are (1) the inorganic chemicals industry, which produces various inorganic cadmium compounds, and (2) industries that use cadmium compounds to manufacture various products. Processes in industries that may generate cadmium-containing wastes are discussed below.

2.1.1 Production of Inorganic Cadmium Compounds

The major manufactured cadmium compounds may be classified into three groups: (1) cadmium pigments, (2) soluble cadmium salts used in the electroplating and battery industries, and (3) high-purity cadmium sulfide and cadmium oxide used in the semiconductor and electronics industries. These classes of materials are discussed separately below.

(1) Cadmium pigments. The term "cadmium pigments" refers to a group of cadmium sulfide-based pigments that range in color from light yellow to deep red. Cadmium pigments are used for the colorization of

plastics, artists' colors, and other quality paints. Differences in color are achieved by adding zinc, selenium, and barium salts to the process.

To produce cadmium pigments, cadmium metal is digested in sulfuric acid to form a cadmium sulfate solution. Often nitric acid is added to increase the reaction rate. A yellow pigment is produced by adding zinc sulfate to this solution and mixing with an aqueous solution of sodium sulfide. A red or orange pigment is made by adding selenium. Barium sulfide is used in place of the sodium sulfide to produce less intense pigments. A few plants also add barium sulfate, in suspension, along with the sodium sulfide as an alternative procedure for generating less intensely colored pigments.

After addition of the sulfide-containing solution (or suspension), the pigment precipitate (chiefly cadmium sulfide) is recovered by filtration, washed, and calcined. The pigment is then ground, rewashed to remove residual traces of sodium sulfate and other soluble materials, redried, and packaged for sale.

Treatment of the wastewaters from this process generates wastewater treatment sludges that contain high levels of cadmium compounds.

(2) Soluble cadmium salts. Cadmium chloride, sulfate, and nitrate are all produced by dissolving cadmium metal in the appropriate mineral acids (Versar 1980). The resulting solutions are then evaporated to recover the desired products. The majority of soluble cadmium salts are used in electroplating operations and as active anode material in silver-cadmium and nickel-cadmium batteries. The small amounts of wastewaters from these processes are generally combined with wastewaters from other production areas prior to chemical treatment before discharge. This chemical treatment normally generates wastewater treatment sludges containing cadmium.

(3) High-purity cadmium sulfide and cadmium oxide. High-purity cadmium sulfide and cadmium oxide are produced by proprietary processes for use in component fabrication operations in the semiconductor and electronics industries. A limited amount of information on these processes has been published (Parker 1978). The available information indicates that cadmium-containing wastes (both nonwastewaters and wastewaters) are likely to be generated by these processes.

2.1.2 Users of Inorganic Cadmium Compounds

The largest single use of cadmium salts is in electroplating operations. Use of cadmium salts in electroplating rinse waters results in the generation of a number of cadmium-containing wastes. Many of these wastes are identified as the electroplating wastes F006, F007, F008, and F009 and are addressed in the Best Demonstrated Available Technology (BDAT) Background Document for F006 (USEPA 1988c) and the Best Demonstrated Available Technology (BDAT) Background Document for Cyanide Wastes (USEPA 1989c).

The second largest use of cadmium compounds is the use of cadmium pigments for colorization of plastics, in artists' colors, and in other quality paints. Use of cadmium pigments involves mechanical formulation operations of paint, ink, and plastic products. The processes used to manufacture these products generate cadmium-containing wastes including rinse waters and spilled and off-specification products that contain cadmium.

The third largest use of cadmium compounds is in the battery industry. Cadmium hydroxide is used as the active anode material in silver-cadmium and nickel-cadmium batteries. Manufacture of these anodes include a number of mechanical pasting operations that may generate spilled materials containing cadmium. Subsequent incorporation of the anodes into finished batteries may generate additional wastes consisting

of off-specification anodes and batteries. Washdown of production areas generates wastewaters containing cadmium. Chemical treatment of the wastewaters generates cadmium-containing waste sludges.

The use of high-purity cadmium oxide and cadmium sulfide in the production of electronic components generates cadmium-containing wastes from component fabrication operations. Most of these wastes consist of particulates and scrap solids high in cadmium content.

Cadmium is also used in small quantities to produce specialty alloys. These operations do not generate significant amounts of waste.

2.2 Waste Characterization

The Agency has waste composition information from 3007 Questionnaire responses from the three current manufacturers of cadmium pigments. The wastewater treatment sludges generated by these facilities contain about 50 percent cadmium sulfide, with smaller amounts of cadmium selenide and zinc sulfide. The Agency also has detailed composition information on the wastewaters from which these sludges were generated from past EPA Office of Water effluent guidelines studies (USEPA 1982).

The Agency also has information from 145 facilities generating D006 wastes. Sixty-three of these facilities generated nonwastewater forms of D006, 76 generated wastewaters, and the remainder generated both (or it was indeterminable which form of waste they generated). Data on these facilities were obtained from the 1986 National Survey of Hazardous Waste Generators (USEPA 1986a). The data in this survey, however, are insufficient to present a comprehensive picture of current waste generated by process and region. Cadmium concentrations in the wastes were as follows:

Below 1 ppm	24 plants
1-10 ppm	46 plants
10-100 ppm	37 plants
100-500 ppm	11 plants
500-1,000 ppm	6 plants
10,000-10,000 ppm	6 plants
10% to 25%	2 plants
25% to 50%	2 plants
Over 50%	2 plants

Twenty-five generators reported generation of wastes that contained organics. Levels of organics present in these wastes were as follows:

Less than 10%	16 plants
10% to 50%	8 plants
Over 50%	1 plant

The organics present were those normally associated with paint, paint removal, or plastics manufacturing (e.g., methyl ethyl ketone, methyl isobutyl ketone, toluene, acetone, methylene chloride, and phthalate esters).

Several facilities showed cyanides to be present. Process descriptions from those facilities indicated the source of the cyanides to be electroplating operations. Most plants reported the presence of other EP-toxic metals in the wastes in addition to cadmium. The metals most frequently identified were lead, zinc, and chromium. Some of these facilities were foundries or other metalworking operations.

2.3 Determination of Waste Treatability Group

EPA believes that wastes with the same waste code produced in different processes in an industry or in different industries may, in some cases, not be treated to similar concentrations using the same technologies. In these instances, the Agency may subdivide a waste code into several treatability groups. This is done when the chemical forms of the wastes are different and the wastes require different treatments

or combinations of treatments. For example, inorganic and organometallic compounds containing the same metals frequently require different types of treatment.

Based on a careful review of available information on the generation of D006 wastes and available waste characterization data, the Agency has determined that D006 wastes comprise three treatability groups: nonwastewaters, wastewaters, and cadmium-containing batteries. The last treatability group includes cadmium-mercury and cadmium-silver cells in addition to nickel-cadmium batteries.

3. APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGIES

Section 2 established three treatability groups for D006 wastes. This section identifies the treatment technologies that are applicable to these groups and determines which, if any, of the applicable technologies can be considered demonstrated for the purpose of establishing BDAT.

To be applicable, a technology must to treat the waste of concern or a similar waste. For detailed descriptions of the technologies applicable for these wastes, or for wastes judged to be similar, see EPA's Treatment Technology Background Document (USEPA 1989b). To be demonstrated, the technology must be employed in full-scale operation for the treatment of the waste in question or a similar waste. Technologies available only at pilot- and bench-scale operations are not considered in identifying demonstrated technologies.

3.1 Applicable Treatment Technologies

3.1.1 Applicable Technologies for Nonwastewaters

EPA has identified technologies applicable to nonwastewater forms of D006 wastes. These are discussed separately in the following subsections.

(1) High-temperature metals recovery. Presently, two types of high-temperature metals recovery operations are in use for reclamation of cadmium for wastes. The first type is used at commercial primary zinc smelters, which accept wastes with high concentrations of cadmium and zinc sulfides. These wastes are blended with sulfide ores and fed to reverbatory furnaces along with coke. Zinc and cadmium metals volatilize from the roasting operation and are collected together by condensation. The crude zinc is then refined electronically to separate the cadmium, which is recovered separately as the metal.

Commercial smelters generally accept cadmium- and zinc-bearing residues only if they have zinc and cadmium content similar to that of the ores normally processed. These facilities normally blend the residues with purchased ore prior to processing. Use of residuals with cadmium and zinc concentrations different from normally used feed materials requires process modifications. For this reason, high-temperature metals recovery using smelters is limited to wastes with cadmium or zinc contents equivalent to the amounts found in common ores.

A second form of high-temperature metals recovery in use for waste treatment is a modification of the standard process for production of zinc oxide. In this process, the waste is blended with coke, silica, and lime and fed to a high-temperature furnace. Chemical reactions occur between the zinc and cadmium sulfides present, oxygen, and carbon to form elemental zinc and cadmium. For cadmium, these reactions are:

$$2CdS + 3O_2 \rightarrow 2SO_2 + 2CdO$$
$$2CdO + C \rightarrow 2Cd + CO_2$$

Elemental zinc and cadmium volatilize and react with oxygen to re-form the oxides. The oxides are then collected from the hot gases emerging from the furnace in baghouses. The impure zinc oxide generated is then purified to separate out cadmium, which is recovered and purified. High-temperature metals recovery is discussed in the Treatment Technology Background Document (USEPA 1989b).

(2) <u>Stabilization technologies</u>. Stabilization technologies involve mixing the waste with binders, such as lime, fly ash mixtures, cement, or concrete mixtures. Water is then added, and the mixture sets into a solid mass that can be land disposed. Stabilization technologies are discussed in detail in the Treatment Technology Background Document (USEPA 1989b).

(3) Chemical precipitation. Chemical precipitation technologies are normally used to treat wastewaters. They may also be used, however, to treat dilute suspensions of solids in water. These technologies will be discussed in Section 3.1.3 on wastewaters.

(4) Incineration. Incineration is applicable to treatment of D006 wastes containing organics. Incineration treatment destroys the organic compounds contained in the wastes. During incineration, some of the cadmium present in the waste volatilizes and is removed as the metal or the oxide in the scrubber water; the rest remains in the solid residue (ash). The residuals (scrubber water and ash) can be treated by the technologies applicable to treatment of wastewaters and nonwastewaters containing no organics.

3.1.2 Applicable Technologies for Cadmium-Containing Batteries

Recovery has been identified as an applicable technology for treatment of cadmium-containing battery wastes. Cadmium may be recovered from these wastes using pyrometallurgical techniques or smelting techniques, as described in Section 3.1.1(1).

Cadmium recovery from cadmium-containing batteries has been practiced in Europe since the 1970s. The metal is removed from liquid wastes by precipitation, flocculation, sedimentation, flotation, and separation and dewatering of the sludge. Pure cadmium metal is obtained through separation by electrolysis (Barring 1983). The Japanese have also developed recycling operations to recover cadmium from cadmium-containing batteries, starting in the 1970s. Cadmium is obtained by feeding the waste materials containing cadmium into a rotary kiln. In the kiln, cadmium compounds are converted to cadmium oxide, which condenses in the cooling zone and is collected in powder form (Ohira 1986).

3.1.3 Applicable Technologies for Wastewaters

(1) Chemical precipitation. Chemical precipitation is applicable to wastewater forms of D006. This technology typically involves addition of lime, caustic, or a sulfide compound to the wastewater solution with pH adjustment. Cadmium hydroxide or cadmium sulfide precipitates from solution and is collected by filtration. The collected solids may then be further treated by high-temperature metals recovery or stabilization prior to disposal. The treated wastewater may be further treated or discharged. Chemical precipitation is discussed in the Treatment Technology Background Document (USEPA 1989b).

(2) Ion exchange. This technology is applicable to treatment of wastewaters containing relatively low concentrations of dissolved metals. The metal must be in a soluble ionic form in order to be removed by this technology. The waste is passed through a bed of ion exchange resin beads. The resin adsorbs the soluble ions, thus removing them from solution. Ion exchange produces both a wastewater residual (from regeneration of the ion exchange resin) and a nonwastewater residual (the spent ion exchange resin). The spent regenerate solutions (usually acid solutions) are more concentrated than the original untreated waste (though much lower in volume) and must be treated for metals removal by chemical precipitation followed by filtration if the regenerate solution is not recyclable. Ion exchange is discussed in detail in the Treatment Technology Background Document (USEPA 1989b).

(3) Electrolytic Recovery. Electrolytic recovery is applicable for treatment of wastewaters containing certain dissolved metals. In electrolytic recovery treatment, an electric current is passed between two submerged electrodes through a solution containing the metal to be recovered. An electrolytic oxidation-reduction reaction occurs in the solution. The dissolved metal is reduced to its pure metallic state and is deposited on one electrode (the anode).

3.2 Demonstrated Treatment Technologies

3.2.1 Demonstrated Technologies for Nonwastewaters

According to 3007 Questionnaire responses on file at the Agency, the three facilities manufacturing cadmium pigments send their wastewater treatment sludges to primary zinc smelters for metals recovery. The second type of high-temperature metals recovery discussed in Section 3.1.1(1) is currently in commercial use treating K061 wastes that have high zinc, lead, and cadmium content. The operations at this facility are described in more detail in the K061 background document (USEPA 1988b). Both types of high-temperature metals recovery are demonstrated for wastes similar to cadmium-containing batteries.

During the comment period, the Agency received information indicating that nonthermal technologies are used to recover cadmium chiefly from spent or discarded batteries. These processes consist of mechanical separation of the cadmium-containing components, which are then shipped to cadmium recovery facilities located abroad. Several of these foreign facilities are primary zinc smelters. Some facilities then subsequently process the noncadmium components to recover other materials such as nickel (National Electrical Manufacturers Association 1990). Residuals from mechanical separation processes must comply with the D006 nonwastewater and wastewater treatment standard.

Stabilization has been used on a commercial basis to treat the listed wastes K061 and F006. Some F006 wastes contain high levels of cadmium, particularly if they originate from electroplating operations producing cadmium-coated products. The commercial use of stabilization to treat F006 wastes is described in the F006 background document (USEPA 1988c).

Incineration is demonstrated for treatment of many hazardous wastes containing organic and metal constituents. These incineration processes

generate scrubber wastewaters and ash that may contain one or more toxic metal constituents which, if they contain cadmium above characteristic levels, must be managed as D006 wastes.

3.2.2 Demonstrated Technologies for Cadmium-Containing Batteries

Cadmium-containing batteries are already being processed on an industrial scale in several countries. The Agency has received information indicating that at least two such facilities are currently operating in the United States. Both of these use the same thermal processes for cadmium recovery.

3.2.3 Demonstrated Technologies for Wastewaters

Chemical precipitation has been in use in the cadmium pigments industry for over a decade as a method for the removal of cadmium from process wastewaters (Versar 1980, USEPA 1982). The specific treatment method consists of sulfide precipitation followed by filtration of the metal sulfide precipitates formed. Cadmium pigment plants generally achieve levels of 0.25 to 0.50 mg/l cadmium in their effluents (Versar 1980). Data on the demonstrated effectiveness of this process are given in the effluent guidelines development document for the inorganic chemicals industry (USEPA 1982).

4. PERFORMANCE DATA

This section presents relevant data available to EPA on the performance of demonstrated technologies in treating listed wastes containing cadmium in concentrations similar to concentrations expected to be found in D006 wastes. These data are used elsewhere in this document for determining which technologies represent BDAT (Section 5) and for developing treatment standards (Section 6). Available performance data consist of full-scale demonstration data as well as bench- and pilot-scale test data for demonstrated technologies.

Performance data, to the extent that they are available to EPA, include the untreated and treated waste concentrations for a given constituent, the values of operating parameters that were measured at the time the waste was being treated, the values of relevant design parameters for the treatment technology, and data on waste characteristics that affect performance of the treatment technology.

Where data are not available on the treatment of the specific wastes of concern, the Agency may elect to transfer data on the treatment of a similar waste or wastes, using a demonstrated technology. To transfer data from another waste category, EPA must find that the wastes covered by this background document are no more difficult to treat (based on the waste characteristics that affect performance of the demonstrated treatment technology) than the treated wastes from which performance data are being transferred.

4.1 Performance Data for Nonwastewaters

Presented in this section are data collected by EPA and submitted to EPA on treatment of various F-code and K-code wastes containing cadmium. These data include performance data for high-temperature metals recovery of K061 wastes and stabilization of K061 and F006 wastes. The Agency

believes that K061 is similar in waste characteristics to many D006 wastes (such as off-specification cadmium chemicals and incinerator ash residues containing cadmium). Additionally, EPA believes that F006 wastes are similar to D006 wastewater treatment sludges in terms of waste characteristics and cadmium concentrations.

4.1.1 Performance Data for High-Temperature Metals Recovery

The Agency has 11 data sets for treatment of K061 waste by high-temperature metals recovery. Tables 4-1 to 4-4 at the end of this section summarize the treatment performance data collected for high-temperature metals recovery for each of the 11 data sets. Seven of the data sets represent data that the Agency collected on a rotary kiln unit (presented in Table 4-1); all other data were submitted by industry and include two data sets from plasma arc furnace treatment (see Table 4-2), one from a rotary hearth electric furnace (see Table 4-3), and one from a molten slag reactor (see Table 4-4).

Table 4-1 presents total composition data for the untreated waste and total composition and TCLP leachate data for the treated nonwastewater residual, as well as design and operating data for each sample set. Table 4-2 presents total composition data for the untreated waste, treated nonwastewater, and treated wastewater, as well as, for Sample Set No. 2, TCLP leachate data for the treated nonwastewater. Treatment for the wastewater is described in detail in the background document for K061 wastes (USEPA 1988b). Table 4-3 presents TCLP leachate data for both the untreated waste and the treated nonwastewater, and Table 4-4 presents EP Toxicity Procedure leachate data for the untreated waste and the treated nonwastewater.

For high-temperature metals recovery, treatment performance is measured by the reduction in the concentration of metal constituents from the untreated waste and also the reduction of leachability of the metals in the residual as compared to the untreated waste.

4.1.2 Performance Data for Stabilization

EPA has performance data for treatment of cadmium-containing nonwastewaters using stabilization, shown in Tables 4-5 and 4-6. The data presented in Table 4-5 are performance data developed from stabilization of K061 waste, while the data in Table 4-6 represent treatment of F006 waste. Both data sets present untreated waste total composition and TCLP data and treated waste TCLP data. These treatments used are discussed in detail in the K061 background document (USEPA 1988b). Table 4-5 also presents design and operating parameters for this test. The data shown in Tables 4-5 and 4-6 are taken directly from the tables presented in the K061 background document (USEPA 1988b). Where values of less than the detection limit are shown, cadmium was not detected in the specific sample.

The Agency also has stabilization performance data from two iron foundries, which are shown in Table 4-7. These foundry wastes contain both lead and cadmium as hazardous constituents. As can be seen, several stabilization formulations reduce both the lead and cadmium EP toxicity test leachates to below characteristic levels. The foundry wastes are likely to be different to treat than K061 and F006 cadmium-containing wastes because of the different raw waste lead and cadmium mix present.

The data shown in Table 4-7 consist largely of individual data points obtained with individual stabilization mixtures. Nevertheless, they demonstrate that stabilization mixtures that which can reduce cadmium levels present in leachates to below characteristic levels.

4.2 Performance Data for Wastewaters

Performance data on chemical precipitation for removal of toxic metals, including cadmium, from wastewaters were developed as part of the effort to establish effluent limitations guidelines for various

industries. The effluent guidelines development document for the inorganic chemicals point source category (USEPA 1982) contains a large amount of data on the effectiveness of various precipitation processes for removal of cadmium from solution, as well as the results of engineering site visit studies at cadmium pigment plants. These data clearly show that with the use of sulfide precipitation followed by filtration, residual cadmium levels in the effluent are reduced to 0.25 to 0.5 ppm, which is well below the EP toxicity limit of 1.0 ppm.

EPA also has performance data for treatment of cadmium-containing wastewaters using chemical precipitation, shown in Table 4-8. These data represent 24-hour composite samples for the concentration of cadmium in treated and untreated wastewaters. The treatment system used was composed of chemical precipitation followed by vacuum filtration. The data in Table 4-8 have been edited to remove data points where the concentrations of cadmium in the treated and untreated waste are both below detection limits. The total data base is shown in the F006 background document (USEPA 1988c).

Additional wastewater treatment data, primarily from EPA's Office of Water, have been analyzed for the development of concentration-based treatment standards for D006 and other wastewaters. Further information on these data, including the sources of the data and the treatment technologies used, can be found in the preamble to the Third Third Final Rule and in the Best Demonstrated Available Technology (BDAT) Background Document for Wastewaters Containing BDAT List Constituents (USEPA 1989d).

Table 4-1 Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Waelz Kiln (EPA-Collected Data)

Constituent[a]	Concentration (units) Untreated concentration mg/kg[b]	Treated concentration mg/kg[b]	Treated TCLP (mg/l)
Sample Set #1			
Cadmium	737	<15	<0.060
Sample Set #2			
Cadmium	345	<15	<0.060
Sample Set #3			
Cadmium	394	<15	<0.060
Sample Set #4			
Cadmium	808	<15	<0.060
Sample Set #5			
Cadmium	857	<15	<0.060
Sample Set #6			
Cadmium	298	<15	<0.060
Sample Set #7			
Cadmium	290	<15	<0.060

[a]Some of the design and operating data associated with these data have been claimed to be confidential. The remaining design and operating data associated with these data are shown at the end of this table.

[b]Reported as ppm in referenced source.

Source: USEPA 1987a.

Waste Characteristics Affecting Performance[a]

Boiling Point (in increasing order) -

Mercury	356°C
Cadmium	765°C
Zinc	909°C
Lead	1760°C
Chromium	2672°C

Boiling Point of Metal - No low boiling point metals are present in concentrations that could impact product (recovered metal) purity and use.

Thermal Conductivity[b] - The thermal conductivity of K061 waste has been estimated to be approximately 28 Btu/hr-ft°F.

Design and Operating Data for Rotary Kiln High-Temperature Metals Recovery

Parameter	Nominal value[c]	Operating value						
		6/2/87			6/3/87			
		SS #1	SS #2	SS #3	SS #4	SS #5	SS #6	SS #7
Kiln temperature (°C)	700-800	760-840[d]	730-820[d]	740-840[d]	720-840[e]	600-1065[e]	575-740[e]	575-740[e]
Feed rate (ton/hr)		-	-	-	-	-	-	-
Rate of rotation (min/rev)		1.5	1.5	1.3	1.5	1.1	1.1	1.1
Zinc content (%)		-	-	-	-	-	-	-
Moisture content (%)		13.3	10.8	11.2	14.7	11.4	14.4	9.2
Carbon content (%)		-	-	-	-	-	-	-
Calcium/silica ratio		3.48	3.33	9.84	5.6	5.89	8.54	8.8

- = This information is considered Confidential Business Information.

[a]The waste characteristics affecting performance for high-temperature metals recovery are relative volatility and the heat transfer characteristics of the waste. As the best approximate measure of the parameters, EPA is using boiling point and thermal conductivity.

[b]Thermal conductivity was calculated based on major constituents present in the waste and their respective thermal conductivities. This calculation can be found in the Administrative Record for K061.

[c]This system was built in the 1920s and was not originally designed for treatment of K061 waste. Nominal values were developed by the plant in lieu of design values.

[d]Values reflect those for kiln #2.

[e]Values reflect those for kiln #3.

Source: USEPA 1987a.

Table 4-2 Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Plasma Arc Reactor

		BDAT constituents detected	
	Untreated waste[a,b] (mg/kg)	Treated slag[b] (mg/kg)	Treated slag TCLP (mg/l)
Sample Set #1 (Stainless Steel)			
Cadmium	100-600	<2	-
Sample Set #2 (Carbon Steel)			
Cadmium	200-900	<10-500	<0.005

- = No data.

[a] For the untreated waste, EPA has values for ranges only. Data were not available on the specific untreated values that corresponded to the treated values.

[b] Expressed as ppm in the referenced source.

Comments:

1. Data were not provided showing the specific operating conditions at the time the wastes were treated.

2. No data were provided on treatment characteristics that affect performance.

Source: SKF Plasmadust 1987.

Table 4-3 Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Rotary Hearth/Electric Furnace

	BDAT constituents detected	
Constituent	Untreated waste TCLP (mg/l)	Treated waste TCLP (mg/l)
Lead	365	0.38
Zinc	4,973	0.94
Cadmium	56	0.05
Chromium	<0.1	<0.1

Comments:

1. Data were not provided on untreated total concentrations.

2. Data were not provided on the design and operating values.

3. Data were not provided on waste characteristics that affect performance.

Source: INMETCO 1987 (Sample Set #3).

Table 4-4 Treatment Performance Data for High-Temperature Metals Recovery of K061 Waste: Molten Slag System

	BDAT constituents detected	
Constituent	Untreated waste EP Tox (mg/l)	Treated slag EP Tox (mg/l)
Lead	348-556	0.05-0.80

Comments:

1. Data were not provided on total waste concentrations.
2. Data were not provided on the design and operating values.
3. Data were not provided on waste characteristics that affect performance.

Source: Sumitomo 1987 (Sample Set #2).

Table 4-5 Treatment Performance Data for Stabilization of K061 Waste (EPA-Collected Data)

Test #1 - Binder: Cement

BDAT constituents	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated waste - TCLP (mg/l) Run #1	Run #2	Run #3
Cadmium	481	12.8	2.86	3.64	3.38

Test #2 - Binder: Kiln Dust

BDAT constituents	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated waste - TCLP (mg/l) Run #4	Run #5	Run #6
Cadmium	481	12.8	2.92	1.80	0.508

Test #3 - Binder: Lime/Fly Ash

BDAT constituents	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated waste - TCLP (mg/l) Run #7	Run #8	Run #9
Cadmium	481	12.8	0.033	0.049	0.073

Note: Design and operating data associated with these data can be found at the end of this table.

Source: USEPA 1988d.

Table 4-5 (continued)

Parameter	Design and Operating Data: Stabilization process/binder								
	Cement			Kiln dust			Lime and fly ash[a]		
	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6	Run #7	Run #8	Run #9
Binder-to-waste ratio	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.10
Water-to-waste ratio	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mixture pH	10.9	11.5	10.5	11.5	11.6	11.1	12.1	12.0	12.0
Cure time (days)	28	28	28	28	28	28	28	28	28
Unconfined compressive strength (psi)	29.7	88.8	95.7	133.0	167.2	141.2	54.8	58.0	50.7

Waste Characteristics Affecting Performance

Fine particulates - 90% of the waste composed of particles <63 μm or less than 230 mesh sieve size

Oil and grease - 282 ppm

Sulfates - 8,440 ppm

Chlorides - 19,300 ppm

Total organic carbon - 4,430 ppm

[a] This binder consisted of equal parts of lime and fly ash.

Source: USEPA 1988d.

Table 4-6 Treatment Performance Data for Stabilization of F006 Waste

Constituent	Concentration					
	Untreated waste		Treated waste - TCLP (mg/l)			
	Total (mg/kg)	TCLP (mg/l)	Binder-to-waste ratio[a] 0.2	0.5	1.0	1.5
Sample Set #1 (Source-unknown)						
Cadmium	1.3	0.01	0.01	NR	NR	NR
Oil and grease	1,520	-	-	-	-	-
TOC	14,600	-	-	-	-	-
Sample Set #2 (Source-auto parts manufacturing)						
Cadmium	31.3	2.21	0.50	0.01	NR	NR
Oil and grease	60	-	-	-	-	-
TOC	1,500	-	-	-	-	-
Sample Set #3 (Source-aircraft over-hauling facility)						
Cadmium	67.3	1.13	0.06	0.02	NR	NR
Oil and grease	37,000	-	-	-	-	-
TOC	137,000	-	-	-	-	-
Sample Set #4 (Source-aerospace manufacturing-mixture of F006 & F007)						
Cadmium	1.69	0.66	NR	NR	<0.01	0.01
Oil and grease	3,870	-	-	-	-	-
TOC	8,280	-	-	-	-	-
Sample Set #5 (Source-zinc plating)						
Cadmium	1.30	0.22	0.01	0.01	NR	NR
Oil and grease	1,150	-	-	-	-	-
TOC	21,200	-	-	-	-	-
Sample Set #6 (Source-unknown)						
Cadmium	720	23.6	3.23	0.01	NR	NR
Oil and grease	20,300	-	-	-	-	-
TOC	28,600	-	-	-	-	-

3197g-22

Table 4-6 (continued)

Constituent	Concentration: Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Treated waste - TCLP (mg/l) Binder-to-waste ratio[a] 0.2	0.5	1.0	1.5
Sample Set #7 (Source-small engine manufacturing)						
Cadmium	7.28	0.3	0.02	0.01	NR	NR
Oil and grease	2,770	-	-	-	-	-
TOC	6,550	-	-	-	-	-
Sample Set #8 (Source-circuit board manufacturing[b])						
Cadmium	5.39	0.06	0.01	0.01	NR	NR
Oil and grease	130	-	-	-	-	-
TOC	550	-	-	-	-	-
Sample Set #9 (Source-unknown)						
Cadmium	5.81	0.18	0.01	0.01	NR	NR
Oil and grease	30	-	-	-	-	-
TOC	10,700	-	-	-	-	-
Sample Set #10 (Source-unknown)						
Cadmium	5.04	0.01	<0.01	<0.01	NR	NR
Oil and grease	1,430	-	-	-	-	-
TOC	5,960	-	-	-	-	-

- = Not applicable.

NR = Results of tests at this binder-to-waste ratio were not reported.

[a] Binder-to-waste ratio = $\frac{\text{weight of binder material}}{\text{weight of waste}}$

[b] Oil and grease and total organic carbon (TOC) have been identified by EPA as waste characteristics that affect the performance of stabilization.

[c] Circuit board manufacturing waste is not in its entirety defined as F006; however, an integral part of the manufacturing operation is electroplating. Treatment residuals generated from treatment of these electroplating wastes are F006.

Source: CWM 1987.

3197g-9

Table 4-7 Stabilization of Ferrous Foundry Wastes

Foundry	EP toxicity test results: cadmium (mg/l)	EP toxicity test results: lead (mg/l)
Foundry 1		
Untreated EP-Toxic Waste Composite	8.8	79
Residuals from the following stabilization methods:		
+25% Magnesium hydroxide slurry	1.7	5.2
+3.9% Phosphoric acid	4.4	9.2
+7.8% Phosphoric acid	0.46	0.16
+10% Phosphoric acid	1.2	0.9
+12.5% Phosphoric acid	0.71	<0.1
+20% Phosphoric acid	3.8	0.4
+10% Metallic iron	6.3	17
+20% Metallic iron	3.1	0.57
+20% Cement	3.0	12.0
+25% Cement	1.4	1.0
+30% Cement	<0.005	0.3
Foundry 2		
Sample #1 Untreated	5.2	88
Residuals from the following Sample #1 stabilization methods:		
+10% Metallic iron	1.9	0.7
+20% Metallic iron	1.9	0.7
+2.5% Phosphoric acid	2.3	0.3
+5.0% Phosphoric acid	1.0	<0.1
+7.5% Phosphoric acid	0.48	<0.1
+7.5% Magnesium oxide	0.029	0.3
+15% Magnesium oxide	0.014	0.9
+22.5% Magnesium oxide	0.005	1.4
Sample #2 Untreated	9.8	85.1
Residuals from the following Sample #2 treatment methods:		
+7.5% Triple superphosphate	2.70	0.34
+10% Triple superphosphate	1.07	0.11
+12.5% Triple superphosphate	0.77	0.15
+15.0% Triple superphosphate	0.68	<0.1
+20% Triple superphosphate	0.43	<0.1
+10% Phosphoric acid	1.2	<0.1
+15% Phosphoric acid	4.0	<0.1
+5% Magnesium oxide + 5% TSP	2.3	0.2
EP toxicity criteria	1.0	5.0

Source: RMT Inc. 1990.

Table 4-8 Treatment Performance Data for Chemical Precipitation and Vacuum Filtration

Constituent	Concentration: Untreated waste[a] composite concentration (mg/l)	Concentration: Treated[a] wastewater concentration (mg/l)
Sample Set #1		
Cadmium	13	<0.5
Sample Set #2		
Cadmium	10	<0.5
Sample Set #3		
Cadmium	5	<0.5
Sample Set #5		
Cadmium	<5	0.5
Sample Set #7		
Cadmium	10	<0.5
Sample Set #11		
Cadmium	23	<5

[a] Untreated waste is a composite of K062, F006, F019, and D002 waste streams. Experimental values are taken directly from the reference.

Source: USEPA 1986b.

5. DETERMINATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the Agency's rationale for determining best demonstrated available technology (BDAT) for D006 nonwastewaters and wastewaters.

To determine BDAT, the Agency examines all available performance data on technologies that are identified as demonstrated to determine (using statistical techniques) whether one or more of the technologies perform significantly better than the others. The technology that performs best on a particular waste or waste treatability group is then evaluated to determine whether it is "available." To be available the technology must (1) be commercially available and (2) provide "substantial" treatment of the waste, as determined through evaluation of accuracy-adjusted data. In determining whether treatment is substantial, EPA may consider treatment performance data from a waste as difficult to treat as the waste of concern. If the best technology is found to be not available, then the next best technology is evaluated, and so on. If no technology is found to be demonstrated and/or available, the waste may be prohibited from land disposal unless a variance is granted to gain time to develop and make available the needed technology.

5.1 BDAT for Nonwastewaters

EPA has identified two treatment groups for nonwastewater forms of D006 wastes. One treatability group is referred to by the Agency as D006 nonwastewaters in the Cadmium-Containing Battery Subcategory; the other treatability group includes other nonwastewater forms of D006 wastes that do not belong to the Cadmium-Containing Battery Subcategory. The Agency has determined that thermal recovery of cadmium is the best demonstrated available technology for the Cadmium-Containing Battery Subcategory. EPA has been unable to quantify a recoverable concentration for cadmium, but

believes that recovery is demonstrated for treatment of all wastes in the Industrial Cadmium Batteries Subcategory.

High-temperature metals recovery (HTMR), such as is demonstrated for treatment of K061 wastes, is also demonstrated for nonwastewaters. As a recovery technology, this is the preferred and best technology for treatment of wastes with high cadmium concentrations. The HTMR residuals will contain much lower concentrations of cadmium than does the untreated waste. Stabilization can be used to treat residuals from either recovery or incineration as well as D006 nonwastewaters that do not have recoverable concentrations of cadmium. Stabilization is the best treatment for these wastes. In the absence of such a cutoff concentration for recovery of cadmium from nonwastewaters, stabilization has been determined to be the best technology for treatment of D006 nonwastewaters other than cadmium-containing batteries. Both HTMR and stabilization are currently available technologies.

5.2 BDAT for Wastewaters

EPA has two data sets for chemical precipitation treatment of wastewaters. One data set, presented in Table 4-7, represents treatment of K062, F006, and other mixed wastewaters containing cadmium. The other data set was obtained from EPA's Office of Water (see USEPA 1989d). Chemical precipitation is the only technology for which the Agency has treatment data for cadmium-containing wastewaters. Therefore the Agency has determined that it is the "best" technology for treatment of wastewater forms of D006. The Agency has determined that well-designed and well-operated chemical precipitation treatment processes can substantially treat cadmium-containing wastewaters. These technologies are available and represent BDAT for D006 wastewaters.

6. DEVELOPMENT OF BDAT TREATMENT STANDARDS

In Section 5, the best demonstrated available technology was identified for each of the three treatability groups (nonwastewaters, cadmium-containing batteries, and wastewaters) identified in Section 2.3. In this section, BDAT treatment standards are developed for these technologies based on the performance data presented in Section 4.

6.1 BDAT Treatment Standards for Nonwastewaters

EPA recognizes the diversity of wastes that qualify as hazardous under the D006 classification. These wastes include those from diverse sources such as paint formulation facilities and iron foundries and are highly variable in composition with respect to both cadmium and other metals. As a result, multiple treatments may be needed for proper management of all constituents. Processes giving optimum results for one type of waste may not do so for all. Because of this diversity, EPA has chosen to regulate D006 nonwastewaters at 1.0 mg/kg in the TCLP leachate. This numerical value represents the level at which the wastes are defined as hazardous. EPA believes even the most difficult to treat D006 wastes can be treated to this level, a level below which the waste will be rendered nonhazardous. Table 6-1 presents the treatment standard for D006 nonwastewaters.

6.2 BDAT Treatment Standards for Wastewaters

EPA recognizes the diversity of wastes that qualify as hazardous under the D006 classification. Based on the data available to EPA, a treatment standard of 0.20 mg/l is achievable for some D006 wastewaters. However, because of the diversity of wastes, EPA has chosen to regulate D006 wastewaters at 1.0 mg/l. This numerical value represents the level at which the wastes are defined as hazardous. EPA believes even the most

difficult to treat D006 wastes can be treated to this level, a level below which the waste will be rendered nonhazardous. Table 6-2 presents the wastewater standard.

6.3 BDAT Treatment Standards for Cadmium Battery Wastes

Because the Agency does not have data on the performance of recovery technologies for the treatment of cadmium battery wastes from commercial and industrial sources, it is unable to establish a concentration-based standard. The Agency is promulgating recovery as a method of treatment for cadmium-containing industrial batteries. Table 6-3 presents the cadmium battery standard.

Table 6-1 BDAT Treatment Standard
for D006 - Nonwastewaters

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Cadmium	1.0

Table 6-2 BDAT Treatment Standard
for D006 - Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Cadmium	1.0

Table 6-3 BDAT Treatment Standard for D006 -
Cadmium Battery Wastes from Commercial
and Industrial Sources

THERMAL RECOVERY AS A METHOD OF TREATMENT

7. REFERENCES

APHA, AWWA, and WPCF. 1985. Americal Public Health Association, American Water Works Association, and Water Pollution Control Federation. Standard methods for the examination of water and wastewater. 16th ed. Washington, D.C.: American Public Health Association.

Barring, N.E. 1983. Recycling of nickel-cadmium batteries and process wastes - processes and operation of the new SAB NIFE plant. In Proceedings, Fourth International Cadmium Conference, San Francisco, California.

CWM. 1987. Chemical Waste Management. Technical report no. 87-117: Stabilization treatment of selected metal-containing wastes. September 22, 1987. Chemical Waste Management, 150 West 137th Street, Riverdale, Ill.

INMETCO. 1987. Description of INMETCO's operations and identification of the materials that it processes. (Industry-submitted data.)

National Electrical Manufacturers Association. 1990. Data submission to the U.S. Environmental Protection Agency, January 8, 1990.

Ohira, Y. 1986. Current status concerning the recycling of sealed nickel-cadmium batteries in Japan. In Proceedings, Fifth International Cadmium Conference, San Francisco, California. London: Cadmium Association; New York: Cadmium Council, International Lead Zinc Research Organization.

Parker, P.D. 1978. Cadmium compounds. In Kirk Othmer Encyclopedia of Chemical Technology. Vol. 4, pp.297-411. New York: John Wiley and Sons.

RMT Inc. 1990. Letter submission of EP toxicity testing data on foundry wastes, January 8, 1990.

SKF Plasmadust. 1987. Key data for the Scandust Plant for treating EAF flue dust (K061). August 1987. (Industry-submitted data.)

SRI. 1989. Stanford Research Institute. Directory of chemical producers, United States of America. Menlo Park, Calif.: Stanford Research Institute.

Sumitomo Corporation of America. 1987. On-site treatment of EAF dust via the NMD system using sensible heat from molten slag. (Industry-submitted data.)

USEPA. 1982. Development document for effluent limiting guidelines (BATEA). New source performance standards and pretreatment standards for the inorganic chemicals manufacturing point source category. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986a. U.S. Environmental Protection Agency, Office of Solid Waste. 1986 National survey of hazardous waste generators. Washington,, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986b. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for Envirite Corporation, York, Pennsylvania. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1987. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report for Horsehead Development Company for K061. Draft report. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988a. U.S. Environmental Protection Agency, Office of Solid Waste. Generic quality assurance project plan for Land Disposal Restrictions Program ("BDAT"). Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988b. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for K061. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988c. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for F006. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988d. Environmental Protection Agency. Onsite engineering report for Waterways Experiment Station for K061. Draft report. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989a. U.S. Environmental Protection Agency, Office of Solid Waste. Methodology for developing BDAT treatment standards. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989b. U.S. Environmental Protection Agency, Office of Solid Waste. Treatment technology background document. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989c. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for cyanide wastes. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989d. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for wastewaters containing BDAT list constituents. Washington, D.C.: U.S. Environmental Protection Agency.

Versar Inc. 1980. Multimedia assessment of the inorganic chemicals industry. Task 4, Contract No. 68-03-2604, final report for the Industrial Environmental Research Laboratory, Vol. 3. Cincinnati, Ohio: U.S. Environmental Protection Agency.